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AN ECONOMIC APPRAISAL OF EFFORT MANAGEMENT ALTERNATIVES FOR THE NORTHWESTERN HAWAIIAN ISLAND COMMERCIAL LOBSTER FISHERY

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PREFACE

This report was prepared by Karl C. Samples of the University of Hawaii and by John T. Sproul of the Western Pacific Regional Fishery Management Council (WESTPAC). It is the result of a two-year cooperative research project on the economics of commercial lobster trapping in the Northwestern Hawaiian Islands. The cooperating agencies include WESTPAC, the Southwest Fisheries Center of the National Marine Fisheries Service (NMFS) Honolulu Laboratory, and the Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii. Karl C. Samples, associate professor of agricultural and resource economics, University of Hawaii is the principal investigator on the project.

Research findings stemming from this project have been documented in a series of separate reports. The first report describes the dynamics of the fishery since 1983 in terms of fleet composition and vessel fishing patterns (Gates and Samples 1986). The second focuses on the post-harvest marketing of lobster products and analyzes the market situation and outlook for NWHI spiny and slipper lobsters (Samples and Gates 1987). The third report in the series summarizes results of a cost-earnings study of three classes of lobster trapping vessels (Clarke and Pooley 1988). A fourth report estimates the potential gains in fleet profitability from effort limitation (Samples and Sproul 1987).

This report is the fifth and final in the series and deals with the economic implications of license limitations, trap and trip limits, and area-season closures. It is intended to provide a point of departure for discussing effort management alternatives and is not intended to recommend one alternative over another. The report contains an academic perspective on the issues that is best utilized in conjunction with experiences and opinions of individuals closely associated with the industry.

The report is being released as a Southwest Fisheries Center Administrative Report because the cost-earnings data which form the basis of the analysis were complied from NMFS logbook files and from the summarized results of an NMFS survey of vessel cost-earnings. However, because the report has been prepared by independent investigators, its statements, findings, and conclusions do not necessarily reflect the views of WESTPAC or NMFS.

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INTRODUCTION

Stocks of spiny lobster, Panulirus marginatus, in the Northwestern Hawaiian Islands (NWHI) have been managed since 1983 under the auspices of the Western Pacific Regional Fishery Management Council (WESTPAC) "to prevent over-fishing while achieving optimum yield (OY) from the fishery on a sustained basis" (WESTPAC, 1982:p.7). OY is defined in biological terms as the maximum number of legal lobsters, an amount that is near, but somewhat less, than the maximum sustainable yield (MSY) for the stock. The same management objective has applied to NWHI stocks of slipper lobster, Scyllarides squammosus, since 1987.

According to the best available scientific information, stocks of spiny and slipper lobsters have been exploited at levels consistent with this management objective throughout early development of the fishery from 1983-86 (Clarke et al., 1987). This was achieved within a regulatory framework that only included minimum size limits.[1]

As the fishery matures and standing stocks of lobsters dwindle under heavy sustained fishing pressure, other regulatory measures may be required to ensure stock conservation. Regulation of fishing effort is one such measure. Aside from resource protection, effort management also may play a role in rationalizing the fishery in terms of economic performance. A revealing vessel cost-earnings study by Clarke and Pooley (1988) shows that despite record revenues in the fishery of $5.9 million in 1986, fishermen as a group earned little or no profits. Low industry net returns appear to be tied to high fishing costs combined with diminished average catch rates. Samples and Sproul (1987) predict that the economic condition of the fishery will deteriorate as stocks of slipper lobsters are fished down from pre-exploitation levels and catch per unit of effort (CPUE) declines accordingly. The 29 percent reduction in overall catch rates for spiny and slipper lobsters from 1986 to 1987 estimated by Polovina et al. (1988) gives substance to this prediction.

There are many regulatory actions that WESTPAC can take to limit the amount of trapping effort directed at lobster stocks. The purpose of this report is to evaluate five different effort management alternatives for which there is no historical precedence of use in the NWHI lobster fishery: license limits, trap and trip limits, and season and large-scale area closures. The intention is to understand which alternatives merit serious further consideration based on: 1) operational feasibility; 2) expected long-run effort reduction potential; 3) expected effect on sustained industry profits over the long-run, and 4) the amount of economic hardship created by control implementation.

For purposes of this report, a control is deemed operationally feasible if it is enforceable, and is consistent with legal standards contained in the Magnuson Fishery Conservation and Management Act (MFCMA) of 1976. In the case of trap limits, for example, the MFCMA does not rule out the imposition of uniform limits on the quantity of gear that vessels can legally carry on-board. Trap limits may also have the advantage that enforcement can occur at the dock rather than on the fishing grounds. Trap counts can be made during inspections before and after trips are made.

The second criteria used to evaluate each control measure is whether it is effective at reducing aggregate sustained fishing effort. Two considerations exist in this regard. First, there is the likelihood that fishermen will simply side-step the control by increasing a non-controlled aspect of their operation. For example, fishermen might respond to a limit on traps carried by increasing the number of fishing days, assuming that the fishing days are not subject to regulation. A second consideration is the potentiality that new boats will enter into the fishery after a control measure has proven effective at increasing CPUE.

Effort control alternatives are also evaluated in this report in terms of potential for augmenting industry profits effort reduction can be a catalyst for enhanced fleet profitability. Consideration is given to the profit consequences of effort adjustment by existing fishermen, and effects caused by new entrants. An additional factor examined here is how a control measure affects operating costs. This is important because all the measures considered here tend to increase fishing costs. The analysis therefore explores the possibility that cost effects may dissipate profit gains.

Creation of economic hardship through effort regulation is also evaluated. Effort controls can create economic harm in two distinct ways, despite well-intentioned efforts to conserve lobster stocks and to promote an economically vigorous harvesting sector. First, certain individuals may have to abandon the fishery. For example, this would be the intentional outcome of a licensing system that did not fully "grandfather" existing participants. A second avenue of economic harm is through increased operating costs and a consequent reduction in short-run profits for participants who continue to fish.

A variety of analytical tools are used in this report to conduct an ex ante evaluation of the feasibility and outcome of effort management alternatives. Theoretical economic models are used to predict how specific control measures will affect sustained effort levels and industry-wide profits. Economic consequences for individual fishing enterprises are also evaluated using these theoretical models. This form of inquiry is supplemented with sensitivity analysis using vessel cost-return summary data reported by Clarke and Pooley (1988). Sensitivity analysis permits a greater appreciation for how control measures might immediately affect the profitability of various types of lobster fishing vessels. Enforcement and other management requirements are postulated based on what is known about the operations of fishing vessels, and about the geographical dispersion of trapping activities and lobster landings in the fishery.

DIRECT EFFORT CONTROL OPTIONS

Fishery managers can select from many different control mechanisms to reduce the level of commercial effort expended in a fishery. These mechanisms can be broadly grouped into two categories: direct and indirect controls. Direct controls over fishing effort place limits on various factors such as fleet size, trip frequency and traps fished that collectively determine industry-wide harvesting capacity. Control is "direct" in the sense that capacity reduction is the management focus. By comparison, indirect controls reduce the productivity of fishermen's harvesting capacity in place, thereby limiting overall fishing mortality. Area and season closures are two indirect controls discussed later in this report.[2]

The capacity of the NWHI lobster fleet to trap lobsters can be reduced directly in many separate ways, and combinations as well. This is illustrated by considering the host of factors that together generated the rapid increase in fleetwide effort levels between 1978-86, and the decline in effort between 1986-87. In 1983, the earliest year for which accurate effort data are available, the total number of trapnights reported fished was 76,857 compared with 902,460 in 1987.[3] From 1983-84, 1984-85, and 1985-86, the number of trapnights fished increased by 415 percent, 174 percent, and 34 percent, respectively. This explosive growth is the result of more and larger vessels fishing with ever greater intensity. In 1987, trapping activity dropped by 38 percent, principally due to the exit of several large vessels from the fishery. Logically it follows that these trends can be accelerated, halted, or actually reversed, by tightly controlling fleet size, vessel size, and levels of fishing activity.

The full menu of direct control options can be illuminated using a simple mathematical expression of fleetwide trapnight production per year (TN/Y):

$$TN/Y = TN/TF * TF/TC * TC/DF * DF/DT * DT/V * V/B * B/Y$$

where:

- TN = trapnights
- Y = year
- TF = traps fished
- TC = traps carried on board
- DF = fishing day
- DT = total days at sea
- V = individual trip
- B = boat

This expression shows that the number of trapnights fished per year depends on six vessel operating characteristics that are determined by each vessel operator (TN/TF, TF/TC, TC/DF, DF/DT, DT/V, DV/B), and on fleet size (B/Y).

The first ratio of trapnights per trap fished (TN/TF) is the "soakrate" of a trap. The soakrate describes how long traps are kept in the water during a set. The ratio of traps fished per traps carried (TF/TC), or the "trap utilization rate," represents the percentage of traps actually used compared to the number of traps carried on board. The ratio of traps carried per fishing day (TC/DF), or "trap capacity," is the total number of traps available for fishing during any given day. The product of these two ratios (TF/TC * TC/DF) yields the average number of working traps fished per day (TF/DF). It represents an important operating characteristic and is significant to management as a basis for effort control. The ratio of fishing days to total days at sea (DF/DT), or "fishing intensity," represents the percentage of fishing days per trip. The number of days at sea per trip (DT/V), or "trip intensity," indicates fishing trip duration. A fishing trip is defined as a single fishing excursion by a commercial lobster boat conducted on a commercial scale in the Northwestern Hawaiian Islands. Multiplying fishing days per days at sea by days at sea per trip (DF/DT * DT/V) yields the number of fishing days per trip (DF/V). The number of trips per boat (V/B), or "annual trip rate," represents another significant operational characteristic with important implications for management. Finally, B/Y is the number of boats active in the fleet on an annual basis.

The wide range of factors which influence aggregate trapnight production (TN/Y) gives rise to a host of possible direct control measures to limit fishing effort, of which only limits on licenses (B/Y), traps carried (TC) and trips (V/B) are considered in this report.

Before analyzing the effects of these specific effort control policies, it is important to appreciate the general operating characteristics of the lobster fleet for two reasons. First, if a control is to be effective at reducing trapnights, then it must be set below current industry operating levels. For instance, it makes little sense to set a maximum trip limit of 100 per year when all fishermen take less than 10 trips annually. Second, the effectiveness of a control measure is lessened when fishermen can readily compensate by adjusting their operations to maintain their previous effort levels. The flexibility to make adjustments depends on whether excess capacity exists in non-controlled operating variables. Knowledge about vessel capacity constraints is therefore critical.

Data pertaining to total days at sea per trip (DT/V), fishing days per trip (DF/V), and trips per boat (V/B) for the years 84-86 are given in Table 1. The data are summarized in terms of vessel Classes I, II, and III. A detailed description of class characteristics is given by Clarke and Pooley (1988). Suffice it to say here that Class I vessels are larger than Class II and III vessels. Class II vessels are differentiated from Class III only by a higher number of traps fished per year and per fishing day by Class II boats.

Between 1984 and 1986, the number of traps fished per fishing day (TF/DF) increased by approximately 45 percent for all classes of vessels. Most of this increase for Class II and Class III boats occurred during 1984-85, with a distinct leveling off thereafter. In contrast, Class I boats managed to steadily expand the number of traps fished through 1986. The average duration for a fishing trip (DF/V) increased throughout 1984-86 for the Class I and III vessels. The rate of increase is most pronounced for Class I boats. Trip length for Class II vessels held relatively constant over the period at approximately 40 days.

Class II boats steadily increased their average number of trips per year (V/B) to a peak of five trips in 1986. The average number of trips taken per boat leveled off at four trips per year for Class I vessels. This trip constraint may in part be a result of the increasing average trip duration for these larger boats. Class III vessels show a high degree of variation in trips taken from year to year. In 1986 the average Class III vessel made four trips. Overall, it appears that vessels in Class II and Class III may be more flexible in the number of trips per year than Class I boats, perhaps due to their ability to make money on shorter fishing trips.

Taken together, these data indicate that existing participants in the fishery are capable of increasing their effort levels by various means. Although many fishermen may already perceive distinct capacity constraints, latitude still exists for the average fisherman to increase the number of traps worked during a fishing day, as well as the number of fishing days per trip. All that is needed to encourage increased capacity utilization is sufficient economic incentive. In addition, given their vessel constraints, fishermen are learning how best to combine trip duration and number of trips per year to augment trapnight production. Establishing this possibility is important to support theoretical predictions of fishermen's operating response to various direct control measures discussed below.

License Limitations

Licensing works to control effort by designating who may legally engage in harvesting activities. Enforcement is relatively simple because those without a license (or fishing permit) are clearly excluded from the fishery. Licensees are granted a right to fish, subject to any existing regulations governing how, where and when fishing occurs.

Operational Considerations

Many different forms of licensing have been used worldwide to reduce the undesired effects of overfishing. Published reviews of licensing programs suggest that their relative success at effectively limiting effort and promoting positive economic returns depends on how the programs are structured and administered (Rettig and Ginter, 1978, Stokes, 1979, Cicin-Sain et al., 1978, Rettig, 1984). Four structural elements that appear to be particularly relevant are: 1) the determination of what is to be licensed; 2) how licenses are distributed; 3) the stringency of renewal policies, and 4) whether licenses are transferable. Ultimately, however, these formal elements of a licensing program, all of which are discussed in more detail below, take a subordinate role to whether the program is conscientiously administered to achieve management goals.

It is not always clear-cut what should be licensed: fishermen, vessels, vessel owners, or gear. Most frequently licenses are tied to individual fishermen (including sometimes legal persons such as corporations). This is true of many commercial fishing licensing programs in U.S. fisheries, including those in Alaska, Hawaii, Michigan and Wisconsin. Assigning licenses to fishermen is also practiced abroad, for example in the Australia lobster and prawn fisheries. The limited entry system in British Columbia salmon fishery is an example of a vessel licensing program (Fraser, 1979).

A second important structural consideration is how licenses are to be distributed. A number of options exist. One method is to sell licenses to fishermen, with no restrictions on how many can be sold. If effort reduction is a goal, then prices must be set high enough to persuade the appropriate number of fishermen to withdraw from the fishery. Although rationing by price can likely achieve effort reduction, the MFCMA explicitly forbids the sale of licenses by a management authority at prices (fixed or auction) that exceed the average cost per license of managing the program. That is, revenues from license sales can only be used to offset management costs. This means that if the intention is to sell licenses to the public, then license prices will, by U.S. law, have to be relatively low. An obvious problem is that a low license price is not a particularly effective way of reducing effort.

Alternatively, a finite number of licenses can be distributed either free of charge or for a nominal fee to enable at least partial recovery of program administrative costs. This is a standard approach to licensing, at least in the U.S., because it is consistent with MFCMA standards and can lead to effort reduction. The potential for such a licensing system to reduce effective effort depends on how many licenses are issued, and on the renewal policy. One way is to set the number of available licenses equal to the number of current vessels or fishermen (or those who fished in the immediately previous season). A moratorium of this type clearly excludes new entrants. While it is true that existing fishermen are "grandfathered" into the fishery (a feature that increases political acceptance), the logic of this type of program is that effort will eventually shrink as fishermen retire or otherwise voluntarily quit fishing on a permanent basis. A second licensing option, that more directly leads to effort reduction, is to judiciously set and maintain the number of available licenses below the amount needed to license all existing fishermen or vessels. In this way some fishing effort is eliminated at the outset of the program.[4] Nevertheless, this system, as well as a simple moratorium, does nothing to constrain the fishing activity of licensed fishermen. As we will see below, this has important implications for the potential for long-term effort reduction.

The effectiveness of licensing with and without initial effort reduction can be enhanced by imposing renewal requirements that provide a legal basis for excluding additional fishermen at the time of license renewal. Renewal requirements that are commonly used include minimum performance levels relating to: 1) percentage of income derived from fishing during the previous year; 2) aggregate years of fishing experience; 3) frequency of fishing activity (for example, days fished or trips taken per year, or sets made per year) during the previous year, and 4) level of capital investment in the fishery. Renewal restrictions can cause the exit of some full-time as well as part-time fishermen, but most active fishermen have no difficulty keeping their licenses. In part this is because they are motivated to fish harder when faced with minimum performance requirements.

An important decision is whether licenses are legally transferable among private parties after initial issue. This decision affects effort reduction rates, and the perceived equity of a program. A common practice, exemplified by the Wisconsin Lake Superior licensing program, is to make licenses non-transferable. Licenses in Wisconsin can be renewed annually only by the person to whom the license was originally issued. This clearly increases the effectiveness of a license moratorium. In stark contrast are programs where licenses are routinely bought and sold. Alaska's licensing program for its salmon fishery is an often-cited example of this system. A restricted number of licenses were originally issued in 1977 in return for a modest fee. Thereafter, the limited supply of licenses was bought and sold in the private market. License prices were bid up (reportedly as high as $100,000) as the present value of fishing profits became capitalized into license values (Karpoff, 1984).

Effort Reduction Potential

It is a mistake to think that licensing is a straightforward way to reduce harvesting capacity. The final outcome is difficult to predict because of complex effort adjustment dynamics in the fishery. Licensing generates downward and upward shifts in industry effort that occur in two distinct phases. During the first phase, some effort is immediately or gradually eliminated, depending on whether all existing participants are "grandfathered" into the program or not. Associated with this effort reduction is an increase in industry CPUE. During the second phase, licensed fishermen respond to higher catch rates and profit potential by increasing their individual effort levels. It is only after both phases are complete that the final effort reduction outcome is realized.

The effects of licensing on effort reduction are tied closely to the economics of fishing and can be analyzed using a simple theoretical bio-economic model of the industry and a typical fishing enterprise, depicted in Figures 1a and 1b, respectively. Similar models are discussed in detail by Anderson (1985, 1986). The starting point for the discussion is the initial level of fishing effort in the unregulated lobster fishery. This effort level corresponds to T_0 in Figure 1a, and is defined by the point of intersection between the total industry revenue curve and the total industry cost curve (before licensing). The typical enterprise (Figure 1b) operates at t_0 level of trapnights and is just financially breaking even. The reason for this zero-profit situation, as hypothesized by Samples and Sproul (1987), is the open-access of the fishery. In theory, effort in open-access fisheries expands until the average financial return per unit of effort just equals the average cost of effort (Gordon, 1954, Scott, 1955). Samples and Sproul (1987) estimated that the open-access equilibrium in the NWHI fishery occurs at 1.4 million trapnights fished on a sustained basis.[5] By fishing this level of effort, fishermen as a group are earning just enough revenue to meet production costs, including the opportunity cost of owners' labor, managerial and investment inputs. A lobster fishery operated in this manner leaves society no better off with the fishery than without it because there are no positive net economic returns from exploitation, and there is no direct return on the economic value of the lobster stocks.

Suppose now that sufficient licenses were issued so that sustained industrial trapping effort was restricted to T_1 level of effort. Ignoring for the moment whether licenses are issued to fishermen or to vessels, this implies a reduction in effort equal to the difference between T_0 and T_1. The reduction could be achieved most rapidly by a restricted license program that excluded some current participants. Alternatively, a moratorium on new permits could be set at a level that corresponded to T_0 level of effort. Through attrition, T_2 might eventually be reached.[6]

Effort reduction during the first phase has important biological and economic consequences. On the biological side, the reduction in sustained effort from T_0 to T_1 will eventually translate into a larger standing stock of lobsters and higher CPUE, all other things being equal. In turn, higher average catch rates represent a clear gain to vessels remaining in the fishery. This is because the combination of a higher CPUE and constant costs enables fishermen to earn a profit illustrated by the shaded area in Figure 1b, assuming they continue to operate at t_0 level of trapnights. Industry profits, shown as the vertical distance AB in Figure 1a, equal the sum of the new profits earned by all fishing enterprises.

Biological and economic gains achieved during the first phase of a licensing program provide a catalyst for subsequent effort adjustments by licensed participants. Reviews of commercial fishing licensing programs by Stokes (1979), and Cicin-Sain et al. (1978) support the contention that although license limits (on either individuals or vessels) reduce effort in the short-run, clear economic incentives exist for fishermen to augment their harvesting capacity through input substitution. In doing so they thwart the purpose of imposing license limitations in the first place. This phenomenon is labeled "capital stuffing." As Rettig (1984) points out, the choice of licensing fishermen or vessels has implications for how capital stuffing would occur in the lobster fishery. If licenses are tied to individual fishermen , then there is a tendency for fishermen to invest in larger vessels, or faster and more efficient trap hauling gear to take advantage of higher prevailing catch rates. Similarly, if vessels rather than fishermen are licensed, incentives exist for vessel owners to modify and upgrade vessels and expand gear and add more labor to their operations. In either case, the argument made by McConnell and Norton (1978), and others, is that if fishing is made more profitable by restricted licensing, then profit-minded fishermen who remain active in the fishery will most certainly find ways to expand their harvesting capabilities, and will continue to do so until the fishery as a whole is no longer profitable.

The additional effective effort exerted by licensees tends to replace part of the effort eliminated through the licensing program. This phenomenon is illustrated in Figure 1B. At t_0 level of effort, individual enterprises will find that extra profits can be earned through effort expansion. A profit-maximizing licensed fisherman will expand effort until t_2 level of trapnights is reached, corresponding to the point where the marginal revenue of effort equals its marginal cost. This effort expansion from t_0 to t_2 has two consequences. First, it raises the industry-wide cost of fishing because the average cost of a trapnight has increased (shown in Figure 1A as the more steeply sloped industry cost curve AD). Second, it also lowers the productivity of effort because the cumulative effects of many fishermen acting in this manner will lower average catch rates below that associated with T_1. Together, these effects will eventually eliminate all incentives for further effort adjustments by licensed fishermen.

For the industry as a whole, a long-run equilibrium is reached at the effort level given by T_2.[6] This effort level corresponds to the intersection of the industry effort supply curve (given by the dotted line segment of the the TOTAL COST curve) and the total industry revenue curve. Clearly, the location of this intersection depends on the costs which fishermen incur to expand enterprise effort beyond t_0. If capacity constraints are severe for fishermen, it may prove profitable for enterprises to make only minor upward adjustments in effort levels. However, considering current capacity utilization in the lobster fishery, upward adjustments could take place over the long run, even without expanding vessel sizes. In other words, if half of the fleet is eliminated through restricted licensing, effective effort will decreased by considerably less than half over the long-run.

Effects on Industry Profits

A close relationship exists between the potential for licensing to reduce sustained effort, and the potential for increased industry profits. It is unambiguous that net returns to fishermen will increase if licensing is effective at reducing effort below current open-access levels. For example, if the final equilibrium level of effort is T_2 in Figure 1a, fishermen as a group would realize profits given by the vertical distance DE.

Creation of Economic Hardship

Displacing fishermen is the principal way that licensing creates economic hardship. Displacement can cause the loss of earning potential, investment value and lifestyle. Earning potential can be reduced if employment opportunities outside of fishing are limited, or if by some chance a highly profitable fishermen does not obtain a license. Investment value may diminish if the resale market for lobster fishing equipment and vessels is depressed. Although there appears to be an active nationwide market for the types of vessels used in the NWHI lobster fishery, it is likely that the resale market for specialty lobster fishing gear would quickly be flooded by displaced fishermen. There is also the loss of lifestyle to contend with, assuming that displaced fishermen cannot find an equally satisfactory alternative way of life.

While it is beyond the scope of this report to completely trace economic hardships, it should be recognized that fishermen and vessels displaced from the NWHI lobster fishery may eventually find their way to other unregulated U.S. fisheries. Transfer of excess effort from one fishery to another could likely create economic hardship in the form of reduced profitability for fishermen already engaged in these other fisheries.

Trap and Trip Limits

Licensing reduces effort by limiting the number of active fishing units, without controlling the harvesting capacity of licensed fishermen. By comparison, regulations that set allowable trap and trip limits reduce industry effort by limiting the harvesting capacity of individual fishing enterprises, without controlling who can legally fish. This difference in management emphasis leads to a profound disparity in how the two strategies affect the operations and profitability of fishing enterprises, and in how industry-wide effort adjustments occur.

Operational Considerations

Aside from control over fleet size and configuration, two basic strategies can be employed to constrain the number of traps fished during the course of a season. Limits can be placed on the quantity of traps used during any particular day, the amount of days that any particular quantity of traps is fished during a season, or some combination thereof. Expressed in terms of the trapnight production model presented above, these strategies translate into limiting the number of traps fished per fishing day (TF/FD), or days fished per vessel (DF/B).

Although placing limits on TF/FD or DF/B may be conceptually sound, restrictions of this type would be prohibitively costly to enforce. Limits on the traps fished per day can probably be policed only by using on-board observers. Observers may also be required to enforce a limit on the number of days fished per vessel. At a minimum, the cumulative amount of fishing days by all participants must be monitored throughout the season. The demands on such a monitoring program would be large because of the unpredictable schedule of many fishing trips. Furthermore, the accuracy of cumulative counts would depend on differentiating between actual fishing days and other non-fishing days spent on the grounds associated with travel, exploration, and gear/vessel maintenance.

Rather than attempting to control traps fished per day, or days fished per vessel, an alternative is to regulate certain components of each. For example, designating an upper limit on the number of traps a vessel can legally carry (TC) may be an effective means of setting trap limits. A limit on TC sets a clear constraint on how many traps can be set in a given day. This in turn limits the maximum number of trapnights fished during an average 24-hour period. Just as limiting the number of traps a vessel can carry places a ceiling on the number of traps fished per day, a limit on the number of allowable trips per season (V/B) constrains a vessel's total fishing days and therefore its trapping capacity. Trap and trip limits have the advantage that enforcement can occur at the dock rather than on the fishing grounds. Counts of traps carried and trips taken can be made using site inspections before and after trips are made.[7]

Two procedures for regulating the number of traps vessels can carry are: 1) to set a uniform upper limit for all vessels, or 2) set multi-tiered limits for different vessel classes. The first alternative is more consistent with fairness and equal treatment standards expressed in the MFCMA because it applies equally to all fishermen. However, uniform limits may be difficult to institute because of the diversity of NWHI lobster fishing operations in terms of the number of traps used. When applying for 1986 NWHI fishing permits, owners of Class I, II, and III vessels reported that they planned to fish 1180, 825, and 764 traps respectively, on the average. The average number of traps actually fished per day for Class I, II, and III vessels was approximately 860, 660, and 420, respectively.

Setting trip limits would begin by determining a total number of allowable trips per year for the entire industry.

Allowable trips could be distributed in at least two different ways. Trips could be allocated on a first-come, first-serve basis. Alternatively, allowable trips could be allocated in equal shares among fishermen or vessels. Both allocation procedures are consistent with fairness standards expressed in the MFCMA, but the operational implications of each differ considerably. What is likely to occur under the first measure is a free-for-all by fishermen, each trying to get their share of trips. An expected outcome would be more trips taken earlier in the season than under normal conditions. Under the second approach, fishermen are assured of a given number of trips for which they can plan for and accommodate changing conditions such as weather, seasonality of harvest productivity, and market prices.

Effort Reduction Potential

The potential for effort reduction through trap and trip limits is realized through two distinct phases of industry-wide effort adjustment. During the first phase, firms cut total trapnight production in response to newly imposed operational constraints. During the second phase, remaining firms respond to higher CPUE by increasing their individual effort levels. New entrants seeking to capitalize on higher industry profits associated with higher catch rates add to this effort expansion because fleet size is not limited (as with licensing).

As in the case of licensing, the dynamics of effort adjustment in response to trap and trip limits can be analyzed using a simple economic model. Although existing fishery economic models do not specifically address trap and trip limits as a means of limiting effort, such limitations fall under the general rubric of vessel and gear restrictions which have been analyzed elsewhere, for example, by Anderson (1985, 1986). Trap and trip limits are similar to other vessel and gear restrictions (such as vessel tonnage or horsepower limits) in that they increase costs by making fishing less efficient. However, a prominent difference is that many vessel and gear restrictions only indirectly limit effort, whereas trap and trip limits directly impinge on fishing intensity.

The effects of trap and trip limits on the industry as a whole, and on the firm, are illustrated in Figures 2A and 2B, respectively. The starting point for the analysis is effort level T_0 for the industry, and t_0 for the firm. This corresponds to the initial open-access equilibrium described above where fishermen as a group are just breaking even financially.

Consider now a limit imposed on the number of allowable traps carried or trips per season that effectively cuts a typical enterprise's trapnight production from t_0 to t_1, <u>assuming that all other inputs are decreased in the same proportion as traps or trips</u>. For example, suppose that the limit involved a 75 percent reduction in the number of trips normally taken by the enterprise. In this case, the level of effort t_1 corresponds to the total number of trapnights used by the typical enterprise given the new constraint on allowable trips, and given a 75 percent reduction in other aspects of the fishing operation such as vessel size, fishing days per trip, and traps fished per day.

The immediate repercussion on the firm is to generate a financial loss situation. At t_1 level of effort, the enterprise's losses are depicted by the shaded area in Figure 2B. The reason for the loss is that the average cost of effort becomes very high at low production levels. This is because fixed operating costs must be spread over a reduced number of trapnights. At t_1, average loss per trapnight is given by the vertical distance AB.

Financial losses created by the initial shock of the new regulation may force some fishermen to leave the fishery. The first to exit would be those who incur particularly high average costs of production at low levels of fishing intensity. Class I vessels would be particularly vulnerable in this regard. With each additional vessel leaving the fishery, aggregate effort falls. This reduction through attrition, combined with the reduction from t_0 to t_1, for all surviving enterprises, eventually leads to an increase in lobster stock size, and consequently an increase in CPUE.

An increase in lobster catch rates sets the stage for a second phase of effort readjustment in the industry. As average revenue per trip increases, profit maximizing enterprises have clear incentive to increase their effort levels beyond t_1. However, this effort expansion comes at higher costs than in the pre-regulatory situation. Given a trap or trip constraint, vessels produce trapnights less efficiently than previously because it takes more inputs to do so.[8] As a consequence, the relevant average cost curve for the enterprise <u>after regulation</u> is everywhere higher than the average for the firm before regulation, at least for effort levels beyond t_1. In Figure 2b, this is shown by the upward shift in the average cost curve after regulation.

The possibility for trapnight expansion beyond T_1 can be illustrated using the example of trap limits.[9] Fishermen would attempt to compensate for trap limits by adjusting their operation to take advantage of higher catch rates. As previously mentioned, trapnight production is a function of several factors, including number of trips per boat (V/B), trip duration (DT/V), and percentage of fishing days per trip (DF/DT). In particular, fishermen's likely response to a trap limit would be to add an extra trip per season. To do this, operators could reduce time in port between trips which would allow time for one or two extra trips in their annual operation. How realistic this is depends significantly on the type of vessel. Smaller vessels capable of shorter gearing-up periods would be more likely to consider this option. Various factors contribute to shorter trips for smaller vessels. For example, smaller boats may reach hold capacity quicker and are more likely to be in port compared with larger boats. Smaller boats would inherently have more days in port to utilize more efficiently. Clarke and Pooley (1988) estimated that an average Class III vessel was at sea 188 days versus 247 days for an average Class I boat in 1986. With the shorter average trip length of 38 days for a Class III boat versus 61 days for a Class I vessel, an additional trip is more plausible for smaller vessels.

However, adding an extra trip will likely raise the average trip costs. Current trip-taking behavior reflects fishermen's attempts to maximize the effective use of their time during the most productive periods of the fishing season. Adding an extra trip could mean fishing during harsh weather and sea conditions. By taking such trips, fishermen incur additional costs for such things as gear replacement and vessel repairs.

The final equilibrium position for the enterprise is t_2 level of effort, where the firm is again just breaking even financially. In equilibrium, the reduction in effort is proportionally less than the original cut from t_0 to t_1. A zero-profit outcome is almost guaranteed given the ever-present potential entry of new vessels into the fleet if positive profit exist. For the industry as a whole, the final equilibrium is given by T_2 in Figure 2A, the level of effort where the new and higher total industry costs equal total industry revenues.

Should management seek to reduce effort levels below T_1, further trap or trip regulations would be required with a corresponding increase in fishing cost. The cost of reducing effort would increase with each successive regulation imposed. Fishermen would bear the costs of further inefficiencies in their operations. Costs encumbered by government would include enforcement of regulations, plan design and policy development, and implementation. Enforcement requirements would increase from simple dockside inspection of traps on board or documenting of trips to using on-board observers for continuous surveillance of fishing operations.

Effects on Industry Profits

Effort regulation in the form of trap limits or trip limits alone does nothing to strengthen the weak profit position of the industry. On the contrary, the effect is to increase fishing costs, while leaving industry profit levels essentially unchanged.[10] Any profits temporarily created from the policy would be dissipated over the long-run. In and of themselves, trap and trip limits will not create conditions sustainable for profitable utilization of the NWHI lobster fishery resource, although they might improve the long-run biological condition of the lobster stocks.

Creation of Economic Hardship

Trap and trip limits impose immediate economic hardship on fishing enterprises by decreasing their harvesting efficiency.

In response, firms that remain active in the fishery are obliged to either cut back on their fishing intensity or meet higher costs to maintain trapnight production at pre-regulation levels. In both cases, the repercussion is a decrease in their profit levels.

The immediate financial effect on fishing firms can be evaluated using vessel cost-earning summary data provided by Clarke and Pooley (1988), and adapted by Samples and Sproul (1987), for the three vessel classes comprising the harvesting sector in 1986. In 1986, the typical Class I, II and III boats fished approximately 860, 660 and 420 traps per day, respectively. Vessels in these respective classes took 4, 5 and 4 trips per year, and earned annual operating profits of approximately $338,000, $275,000 and $60,000.[11]

The sensitivity of vessel profits to changes in the number of traps fished per day, and trips taken per season is illustrated for all three vessel classes in Figures 3A and 3B, respectively. The economic repercussion of changes in traps fished and trips taken is directly related to vessel size and productive capacity. This is because traps and trips are more productive, on the average, as vessel operating scale increases. This is simply due to the fact that larger vessels are able to combine traps and trips with other variable factors of production more efficiently so as to make the entire input mix more profitable. On the average, each 100 traps fished per day during 1986 contributed $110,000, $86,000 and $61,000 to the annual profits of Class I, II and III vessels respectively. For the respective classes, each trip taken contributed $122,000, $67,000 and $28,000 to annual operating profits.

It follows, therefore, that any absolute or relative reduction in traps fished or trips taken will impose the greatest economic loss on Class I vessel owners. This is especially true for trap limits. For example, an industry-wide limit of 400 traps fished per day would leave Class I vessels with negative operating profits. By comparison, smaller Class II and III vessels would remain profitable to operate with this trip limit. However, Class I vessels may be more capable of handling the financial repercussions of trip limits compared with Class III vessels. Although each trip is worth less to the smaller boats in terms of absolute contribution to profits, Class III vessels need more trips than Class I boats to earn a profit. If a two-trip limit was imposed for all vessels, then Class III vessels would not be able to earn a profit.

Given the multi-class nature of the existing NWHI lobster fleet, an across-the-board trap or trip limits per boat would have serious economic implications for all vessel types, but the greatest <u>losses</u> would accrue to Class I boats. This is because regulation of fishing effort using trap or trip limits are strongly biased against larger vessels that realize economies of scale in their operations. With trap or trip limits in place, profit-minded fishermen would continually scale down their operation to perform at least cost. Given time for complete effort re-adjustment, the fleet would probably evolve to smaller boats that operate more efficiently at lower effort levels.

INDIRECT EFFORT CONTROL OPTIONS

Commercial fishing regulations typically aim more at stock conservation rather than effort management per se. Commonly used regulations on allowable catch (for example, minimum size, quotas, species, incidental catch) and restrictions on the time and place of fishing are examples. Nevertheless, because these regulatory measures tend to reduce fishermen's productivity, their implementation can lead to reductions in industry-wide fishing effort. But the causal link between regulation and effort reduction is indirect and tenuous.

It was established in the discussion above that direct effort control regulations have ambiguous outcomes given fishermen's ability to substitute inputs, and given the ever-present possibility of effort expansion caused by new entrants. This is true even though direct controls put clear limits on productive inputs used in fishing. Indirect controls, by comparison, do nothing explicitly to constrain the amount of physical inputs devoted to fishing. Instead, their immediate effect is to reduce fishing profitability by reducing gross earning potential, increasing operating costs, or some combination of both. By adversely affecting short-run vessel profitability, indirect controls encourage fishermen to decrease effort. In the long run, however, effort may be readjusted upward in response to increased catch rates.

Season and area closures are two indirect effort control measures considered in this report. Season closures in lobster fisheries are justified primarily on biological grounds; most commonly to safeguard stock recruitment and protect the reproductive capacity of the stock (Caddy, 1983).[12] Closures normally coincide with times of peak molting and spawning periods so as to protect vulnerable egg-bearing females. Lobster fisheries with closed seasons include those in Australia, Canada, Europe, Florida and New Zealand, to name only a few (Hancock, 1981, Wilder, 1962, DeWolf, 1974, Bennett, 1981, Davis, 1981, Annala, 1983). Area closures are also usually justified on biological grounds, and focus on protecting nursery zones for juveniles or unique breeding sites for spawning adults. Area closures are used in the lobster fisheries in Australia and France to protect areas important to the reproductive capacity of the fishery (Hancock, 1981, Bennett, 1981).

Season Closures

Operational Considerations

There are countless available alternatives for dividing a year into closed and open seasons to control when lobster trapping may legally occur in the NWHI. Selection of any one option requires making a decision about the number of openings and closings, their inclusive dates, and the geographic areas affected by each season.

Perhaps the most simple season closure policy for the NWHI lobster fishery is to have only one open season and one closed season within the calendar year for the entire archipelago. It is difficult, however, to justify such a policy for the NWHI based purely on stock conservation arguments. This is because the lobster stocks do not clearly display exclusive spawning seasonality (Uchida and Tagami, 1983). Recent research indicates that pronounced spawning activity occurs only in the northern-most reaches of the NWHI where slipper lobsters spawn from March through June, and spiny lobsters from May through August (Uchida and Tagami, 1983, MacDonald, 1987). By comparison, spawning takes place all year in the southern-most reaches of the Hawaiian archipelago (Morris, 1968). Therefore, while a season closure from March through August may be considered biologically justifiable for the northern NWHI, no biological rationale exists to extend such a closure throughout the archipelago.[13]

Ignoring biological considerations, if the goal of a single season closure is fishing effort reduction, then it would be most effective if lobster trapping is prohibited during those periods when fishing intensity has historically been high. Peak fishing activity for the years 1984-86 was between March and August, and during November and December (Figure 4). Therefore, a single season closure, either from March through August, or from November through December, appears to be a feasible way to limit fishing effort.

A second basic option is to institute a schedule of multiple closures for the entire NWHI, whereby fishing would be opened and then closed on several occasions during the year. Although there is again no clear biological justification for designating any particular closure periods, the use of multi-seasons allows more selective control over fishing intensity and a consequent reduction in the absolute amount of time that fishing is closed. For example, suppose the management goal is to reduce effort by 30 percent using season closures. Based on 1986 fishing patterns, the fishery would have to be closed at least three months (from July through September) to achieve the desired result. By comparison, the same reduction could be achieved using multiple closed seasons by prohibiting fishing during the two peak months of August and November.

A third option is to apply season closures in specific areas rather than the entire NWHI. For example, closing only the northern-most part of the island chain during the spring and summer periods of peak spawning activity may be justifiable on biological grounds. However, such an area-specific closure would have little impact on reducing total fishing effort because historically only about 2 percent of the annual effort in the NWHI lobster fishery is directed at stocks in this area (WESTPAC, 1986b). Other, and perhaps more effective, geographic-specific closure options are discussed in more detail below under the topic of area closures.

All three of these basic season closure options are consistent with national fishery management standards contained in the MFCMA, provided that the closures are applied across-the-board to all participants.[14] The first two approaches, involving closures for the entire fishery, also have the attractive attribute of relatively low monitoring costs and ease of enforcement. This is not true of the third option where fishing is prohibited only in certain areas during closed seasons. With general closures, little question exists whether fishermen are complying or not. If lobsters are landed during the closed season, a violation has surely occurred. The monitoring procedure is eased for the NWHI lobster fishery since Honolulu is the primary off-loading port. Enforcement would be limited to dockside inspection and existing flight surveillance of fishing grounds.

Effort Reduction Potential

To be effective as reducing industry-wide effort, season closures must constrain the total available time that fishermen can productively engage in trapping activities. All other things being equal, the longer the closure, the more binding the constraint on fishing opportunities. By limiting available fishing time, a season closure works like a trap or trip limit to restrict fishermen's use of otherwise efficient input combinations. In this sense the effects of the two types of regulatory instruments are so similar that the theoretical economic models discussed for trap and trip limits can be used to interpret effort adjustments in response to closed seasons.

Faced with a new operating constraint, the typical fisherman responds by trying to circumvent the restriction by fishing more intensely during the open season. This would likely entail increased use of physical inputs such as traps, fuel, or more efficient trap-hauling equipment as replacements for the reduction in allowed fishing time. However, the substitution of physical inputs for fishing time is less than perfect. Costs per trapnight will increase above pre-regulatory levels because increased fishing activity has to be compressed into a fewer number of fishing days available during open season.[15] This cost increase will motivate profit-minded fishermen to adjust their effort levels downward (from t_0 to t_1 in Figure 2b), but the cut will be less than proportional to the total loss in fishing days associated with the closure. Nevertheless, the short-run result is at least a modest effort reduction for the industry as a whole.

Just as with direct controls, an industry-wide reduction in effort will lead eventually to improved fishing conditions as the lobster stock size grows and trapping productivity increases. The direct correlation between lobster harvesting CPUE and season closure duration is well documented by Baisre et al. (1983), with longer closures generating relatively greater increases in CPUE during the open seasons. A higher CPUE will encourage even greater fishing intensity. Effort for the firm expands from t_1 to t_2 (Figure 2b), thereby further reducing the effectiveness of the closure. A final equilibrium for the industry is reached where total costs equal total revenues (at effort level T_1 in Figure 2a).

The tendency for season closures to promote cost escalation in lobster fisheries has been documented for the Australian and Canadian fisheries. Wilder (1962) reported that dramatic increases in exploitation rates and fishing effort occurred during shorter open seasons in the lobster fishery of the Canadian Maritime Provinces. Economic incentives associated with higher CPUE drew participants out of other industries and this negatively affected earnings of regular fishermen. Greater financial returns per unit of effort also motivated regular lobstermen to fish intensely. In short, more men, boats and traps were employed. Similar experiences in the western rock lobster fishery of Australia also indicate the marginal effectiveness of season closures to reduce trapping effort (Morgan, 1980, Hancock, 1981).

Effects on Industry Profits

Season closures are generally considered an economically inefficient mechanism to regulate effort because they encourage wasteful intertemporal reallocation of effort as participants increase fishing activity during open seasons (Clark, 1976, Scott, 1979, Panayotou, 1982, Caddy, 1983, Anderson, 1986). The principal economic ramification of implementing season closures in a fishery is an increased average cost of fishing effort which translates into higher harvesting costs for the industry as a whole. Although increases in CPUE associated with effort reduction eventually make trapping more productive, this only leads to greater fishing intensity and still higher costs. The end result is a new open-access equilibrium, with fishermen earning zero profits.

Marketing ramifications, both positive and negative, are known to occur from season closures. On the positive side, closures can force landings to occur when prices and demand are highest, and product quality is also best. In the Maritime Provinces of Canada, for example, season closures prevent large Canadian landings from coinciding with peak periods of production (and low prices) in the U.S. (DeWolf, 1974). On the negative side, season closures can result in marketing bottlenecks and correspondingly higher storage costs associated with the required freezer space necessary to spread the catch over the full marketing period (Crutchfield, 1965).

Creation of Economic Hardship

To the extent that season closures reduce available fishing days, they have a detrimental economic impact on commercial lobster trapping operations. A closure of any given duration would most affect full-time lobster trapping operations that are relatively active on a year-round basis, and would least affect part-time operations that engage in trapping activities only sporadically.

Clearly the more active a vessel, the more difficult and costly it becomes to shift effort from closed to open seasons. In this regard, Class I, II and III vessels fished 199, 151 and 138 days in 1986, respectively. Class I boats, therefore, would be expected to lose more fishing days compared with Class III boats, for any given season closure length. The sensitivity of Class I, II and III vessel profits to changes in fishing days is depicted in Figure 5. Class I and II vessel profitability is more sensitive to reductions in fishing days compared with Class III boats. This is because of the relatively higher daily productivity of Class I and II operations.

However, this analysis overstates the losses that fishermen would expectedly incur because lost fishing days can be compensated for by increasing trapping activity during open seasons. Fishing more traps per day is one immediate strategy. Class II vessels appear to be most restricted in this regard, based on the earlier discussion of vessel operating characteristics. Class I and III boats may be more able to exploit daily trapping capacity that is currently underutilized.

Area Closures

Area closures are little more than seasons applied to specific locations. Permanent closures imply that the fishing season in a particular area is never open. Rotating closures imply that the fishing season for a particular area is open and then closed on some cyclical basis. Area closures therefore simply add a spacial dimension to the temporal dimension that defines closed seasons.

Operational Considerations

There has been only limited experience in using area closures in the NWHI lobster fishery. In March 1983, two permanently closed areas were designated in the spiny lobster fishery: 1) within the fishery conservation zone landward of the 10 fathom contour, and 2) within 20 nautical miles of Laysan Island. Effective October 1986, all lobster fishing was excluded from these areas. The objectives underlying these closures had little to do with either stock conservation or effort management. Instead, the areas were set aside to protect the integrity of critical habitat designated for endangered species such as the Hawaiian monk seal (*Monachus schauinslandi*), and to establish a control area (Laysan Island) for assessing the impacts of commercial fishing on lobster stocks (WESTPAC 1982, WESTPAC, 1986a).

There is no clear biological justification for extending area closures beyond these narrow geographical bounds. No single area seems to serve as a nursery zone. In fact, it is altogether uncertain whether larval recruits into the NWHI lobster fishery come from a central location, or from multiple sources distributed throughout the archipelago (MacDonald, 1985). Similar uncertainly surrounds the relative importance of any particular area as a center of spawning activity.

Notwithstanding the lack of a clear conservation motive, area closures can nevertheless be used to reduce fishing effort directed at lobster stocks. In the absence of any specific proposed area closure policies, three alternative approaches are conceptualized here.

The first area closure concept is to divide the NWHI fishery grounds into two or more equal-sized areas, each to be fished on an annual rotating basis. Latitude or longitude coordinates could be used to demarcate areas. Although simple, this approach does not account for differences in the amount of effort historically expended in each area. Consequently, industry-wide effort levels could vary greatly from year to year depending on which areas are open. A second area closure strategy is to carefully divide the NWHI into separate areas in such a way that each is similar in terms of the amount of fishing effort historically attracted to it. By closing areas on an annual revolving basis, a certain constant percentage of industry-wide effort would be displaced every year. A third area closure concept is to treat each fishing bank as an individually manageable unit. Effort reduction is then approached on an area-specific basis. As soon as cumulative trapping activity reaches a pre-determined level, the bank is closed to fishing for the remainder of the year.

The costs of enforcing area closures is probably higher than those associated with season closures. This is because on-site surveillance would be required to assure that closed areas remained unfished. Required monitoring intensity would be directly related to the number of closed areas. In the case of closures involving many independently-managed areas, on-board observers may be required to radio back detailed information regarding daily levels of fishing effort exerted in specific areas. Such a procedure would be necessary to ensure area closures occur promptly and are not delayed by the need to wait until boats return to port to determine level of fishing per area. This need is especially acute when trips are of long duration and target effort levels could easily be exceeded.

Effort Reduction Potential

Of the three different closure options just outlined, only the multi-area sequential closure plan can lead to an unambiguous reduction in total effort. This outcome is achieved by directly limiting effort in each area. Assuming that proper attention is given to closing the areas at the proper time, then the cumulative level of effort exerted by fishermen across all areas will equal target levels.

The other two more simple forms of area closures can also lead to effort reduction, but the process is complex and occurs in several distinct phases. For purposes of illustration, consider a closure arrangement in which two broad areas A and B are designated to be opened and then closed on an annual revolving basis, and historical levels of fishing effort in both areas is the same. Fishing is prohibited in area A during the first year that the policy is enforced. During that year, at least some of the trapping effort that is normally exerted in area A is diverted into area B. The reverse happens in the second year, and so forth. During each cycle, an area has a one-year "fallow" period with no exploitation taking place, followed by a year of intensive exploitation.

To have an effect on total annual effort, the diversion of trapnights between areas must be less than 100 percent. There are two economic incentives that could make this happen: increased fishing costs and decreased average CPUE. Anderson (1986) contends that fishing costs for the firm and the industry as a whole will increase with the introduction of closed areas. Scott (1979) makes similar arguments, but like Anderson he appears to be discussing permanent closures that force at least some fishermen to travel further than previously. In such instances, average transportation expenses will increase, thereby making effort more costly. The argument for cost augmentation is less convincing in the case of rotating closures because travel distances for all participants, averaged over a two-year period, are unchanged from pre-regulatory levels.

There is reason to suspect, however, that instituting a revolving area closure system would eventually lead to a fall in CPUE. The reduction is tied to the fact that the stock of lobster available to the fishery during any given year is a fraction of the total stock available to the industry prior to the initiation of area closures. This is true despite the one-year fallow period between harvesting opportunities.[16] A smaller harvestable standing stock translates into reduced harvesting revenue for any given effort level. This is depicted as a downward shift in the industry total revenue curve given in Figure 6. Assuming harvesting costs are essentially unchanged, the open-access effort in the fishery falls from T_0 to T_1 as a result of the closure. Any upward change in fishing costs would lead to even a greater effort reduction.

Effects on Industry Profits

Generally speaking, area closures have no effect on industry profit levels, assuming that effort is not otherwise constrained. The end result is simply a new open-access equilibrium involving less effort than before, with fishermen just breaking-even financially.

Area closures could also have negative affects on the lobster marketing process. Specific fishing grounds in the NWHI's are known to have different average sized animals (Clarke, et al. 1987). Area closures may cause the size composition of landings to be more pronounced over time. Reduced year round availability of desirable sized animals will cause difficulties for distributors to market Hawaiian caught lobsters (Samples and Gates, 1987). In addition, intense fishing pressure on the best grounds early in the season would cause "bulges" in landing levels and generating marketing bottlenecks.

Creation of Economic Hardship

Concentration on the profit situation for the industry as a whole disguises the fact that the downward change in effort associated with area closures occurs via the attrition of inefficient operations. The initial effect of the closures is to lower catch rates for the industry. Enterprises with high operating costs would be the first to feel the cost-revenue squeeze. Over the longer run, operations with high fixed costs would be disadvantaged by the reduced contribution margin of each trap fished. Class I vessels would be particularly susceptible in both regards, while Class II boats would probably be the most resilient.

For those enterprises that weather the financial negative effects created by the initial reduction in catch rates, the long-term outlook is brightened by a gradual increase in catch rates over time in response to the initial effort reduction. The final outcome for these enterprises is a situation very similar to the pre-regulatory situation, at least in terms of financial rewards.

CONCLUSIONS

The NWHI lobster fishery has matured rapidly since 1983, the first year of conscientious management. Maturation is evident both in terms of the skill and sophistication of participating fishermen, and in the conditions of lobster stocks which today stand at a fraction of pre-exploitation levels. As this valuable fishery passes from a stage of rapid development to the steady-state, control over trapping levels takes on greater importance.

Although no specific effort management strategies have been formally proposed for the fishery at this time, this report assesses five different types of regulations in terms of their legal and enforcement feasibility, potential for effort reduction, effects on industry profits, and creation of economic hardship. The set of regulations evaluated here is in no way exhaustive of the available repertoire. To be complete, the analysis would also address other tools such as catch restrictions and quotas (for individuals or the industry), and price disincentives such as landings taxes, to name but a few.

Two simplifying assumptions have guided the analysis, both of which bear heavily on the predictions contained herein. First, it has been assumed throughout that fishermen behave as well-informed profit-maximizers, and make continuous adjustments in their fishing operations in response to new input constraints and changing catch rates. This assumption is the basis for predicting the pattern of downward and upward effort adjustments by individual enterprises which together ultimately determine changes in industry-wide effort. To the extent that fishermen behave according to motives other than profit, these predictions may be incorrect. The second assumption is that the each regulation measure is implemented on its own. No attempt made to consider multi-dimensional effort management measures. Nevertheless, a preliminary step in this direction would be to simply sum effects of individual regulatory instruments as described above.

In terms of regulatory feasibility, all five management measures considered here generally are enforceable and are consistent with MFCMA standards, but this depends on regulation specifics. For example, some area closure schemes (such as the individually-managed multiple area system) would be extremely expensive to enforce, while others (such as a simple two-area rotating system) could probably be enforced using existing levels of surveillance in the NWHI. Similarly, some licensing schemes that involve exorbitant license fees are clearly inconsistent with MFCMA guidelines, while other systems, including a simple license moratorium, are legal.

With regard to effort limitation, a primary conclusion of this report is that all five regulatory measures generate effort reduction (Table 2). A second conclusion is that the process of dynamic adjustment is complex and depends on the responsiveness of fishermen to changing economic conditions, and the sensitivity of CPUE to changing sustained effort levels. The effort adjustment process appears to occur in three phases. During the first phase, fishermen respond to new constraints by lowering their trapping intensity. This phase may be short-lived before the second phase begins during which fishermen make appropriate adjustments in their overall input mix to squeeze as much profits out of their operations in the face of the new regulation(s). During the third phase, the biological effects of earlier effort reduction are manifested in the form of higher CPUE. This motivates a final expansion in effort.

The long-run effects of effort management regulations on industry profits is mixed (Table 2). Only licensing can generate higher profits due to the physical limits placed on effort expansion by licensed operators. With the other tools, all potential for increased industry profits is eroded by increased costs or decreased revenues for enterprises, or by the potential entrance of new enterprises into the fishery.

Finally, it is clear that with the notable exception of a licensing system that "grandfathers" all existing participants, the regulatory measures considered here create economic harm in some way or another. Displacement from the fishery is one source of harm. Fishermen may be obliged to stop lobster fishing either directly through limited licensing, or indirectly by their inability to cope with short-run financial losses. Economic harm is also realized by the short-run effects of regulations on decreased vessel capacity utilization, and associated cost increases. Only licensing avoids this effect (Table 2).

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P 30

ENDNOTES

[1]The disequilibrium condition of NWHI lobster stocks throughout the recent history of commercial lobster fishing makes it difficult to determine if in fact the maximum number of legal lobsters was obtained during the "fishing down" phase of lobster exploitation. It appears, however, that harvesting rates exceeded MSY levels for the years 1984-87 (Polovina et al., 1988). This would be expected as fishermen began targeting on previously unexploited fishing areas and species.

[2]Many economists include price disincentives such as license fees and landings taxes in the category of indirect effort control measures. Price disincentives are largely precluded by the MFCMA and are not considered here. The MFCMA does not explicitly prohibit any of the other direct and indirect effort control options otherwise discussed in this report.

[3]A "trapnight" is the standard measurement unit of fishing effort in the NWHI lobster fishery. A trapnight is defined as a single trap left in the water overnight. The measure includes a physical dimension (a trap) and a temporal dimension (time left in the water). Its adoption stems from the fishermen's practice of "soaking" their traps in the water for a single night, on the average.

[4]This raises the question of who will be excluded and who will remain in the fishery. In view of the importance that the MFCMA places on equal treatment of all participants, it is doubtful that immediate effort reduction is a legally admissible policy alternative.

[5]This estimate was based on 1986 estimates of MSY for spiny and slipper lobsters combined, which have since been revised downward (Polovina et al., 1988). The long-run open-access equilibrium is therefore less than 1.4 million trapnights, perhaps by as much as 50 percent.

[6]It is difficult to predict how long it would take for this attrition to occur. Historically, turnover in the fishery has been relatively high, but this appears to be related almost entirely to profit seeking entry-exit behavior by vessel owners who are flexible in the choice of fishing activities (Gates and Samples, 1986). Licensing reduces this flexibility, but it is unclear whether this will encourage exit from or closer affiliation with the NWHI lobster fishery.

[7]Obviously, this does not rule out the possibility of fishermen caching strings of traps in the NWHI to be retrieved and used upon arrival.

[8]The extent of efficiency losses depends on the rate of technical substitution of other inputs for displaced traps or trips. The analysis presented here assumes that less than perfect substitution exists in the industry; hence, the efficiency loss and cost increase.

[9]Enterprises may be able to overcome a trip limit by extending the duration of each fishing trip to include more active fishing days. Longer trip duration may necessitate having to be re-supplied with bait, water, groceries and so forth using air drops or some type of mothership operation.

[10]This is exactly the outcome of a recent trap limitation program instituted in the Australian rock lobster fishery (Staniford, 1987).

[11]Although firms in all vessel classes earned positive operating profits in 1986, industry-wide economic profits in 1986 were essentially zero after accounting for all opportunity costs of labor and capital inputs (Clarke and Pooley, 1988; Samples and Sproul, 1987). The sensitivity analysis presented here is based on vessel operating profits, the profit indicator that fishermen generally pay most attention to.

[12]See Everson (1986) for a summary of closed seasons for lobsters in various fisheries around the world.

[13]Since 1925, a closed season has been observed in the State of Hawaii for the spiny lobster and slipper lobsters during June, July, and August (Everson, 1986, DLNR, 1985). This closed season places harvesting limits on the recreational fishery during peak spawning periods (Everson, 1986).

[14]There may be legal and political opposition to using season closures to control effort when no biological justification exists for their implementation. The lack of a clear conservation overtone may lead to the perception that the tool is being improperly applied, or is being used surreptitiously.

[15]The extent to which operating costs increase probably depends on the duration and timing of the closure(s). A five-day closure will affect operators less than a 30-day closure. Similarly, of three one-month closures distributed throughout the year will probably have less impact than a single three-month closure.

[16]No attempt has been made to prove this assertion. But assuming stocks are uniformly distributed across areas, stocks in any area would have to more than double in size during the fallow period in order to maintain CPUE at pre-closure levels. This seems like a doubtful possibility for lobsters.

TABLE 1. Average Vessel Trip Performance by Vessel Class: 1984-86

Vessel Class	Year	Sample Size	Average Number of Trips Per Boat (a)	Average Number of Days Per Trip (a)	Average Number of Traps Fished Per Fishing Day
CLASS I					
	1984	3	3(1)	53(15)	591
	1985	4	4(1)	51(24)	776
	1986	5	4(1)	61(21)	861
CLASS II					
	1984	3	3(2)	42(18)	453
	1985	3	4(2)	38(16)	660
	1986	3	5(2)	39(12)	659
CLASS III					
	1984	4	4(3)	19(8)	294
	1985	5	7(2)	33(17)	396
	1986	7	4(2)	37(17)	418

SOURCE: NMFS Database
NOTE: (a) Sample standard errors given in parentheses

TABLE 2. PREDICTED EFFECTS OF EFFORT CONTROL MEASURES

Control Measure	Effects on: (a) Sustained Effort	Industry Profits	Average Vessel Capacity Utilization
Licensing	-	+	+
Trip Limits	-	0	-
Trap Limits	-	0	-
Season Closures	-	0	-
Area Closures	-	0	-

NOTE: (a) "0" = no change; "-" = reduction; "+" = increase

FIGURE 1A.

EFFECTS OF LICENSING ON THE INDUSTRY

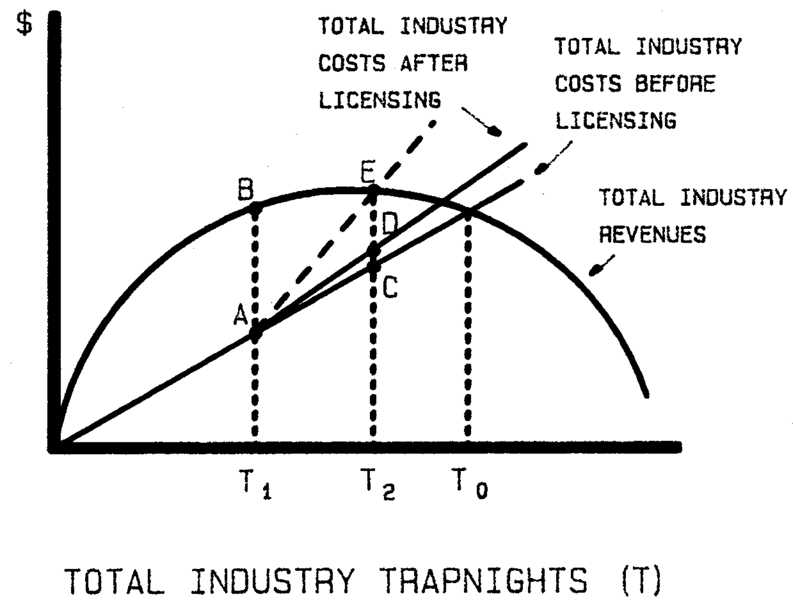

FIGURE 1B.

EFFECTS OF LICENSING ON THE TYPICAL ENTERPRISE

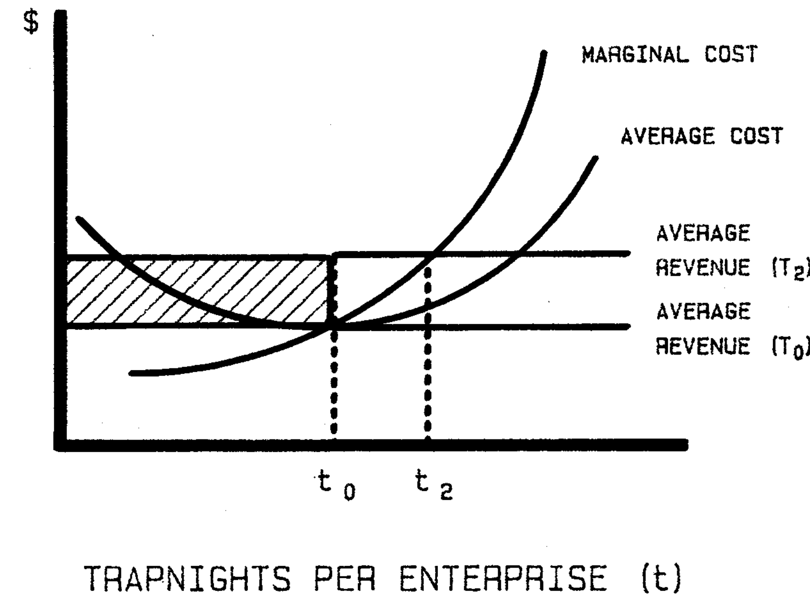

FIGURE 2A.

EFFECTS OF TRAP AND TRIP LIMITS ON THE INDUSTRY

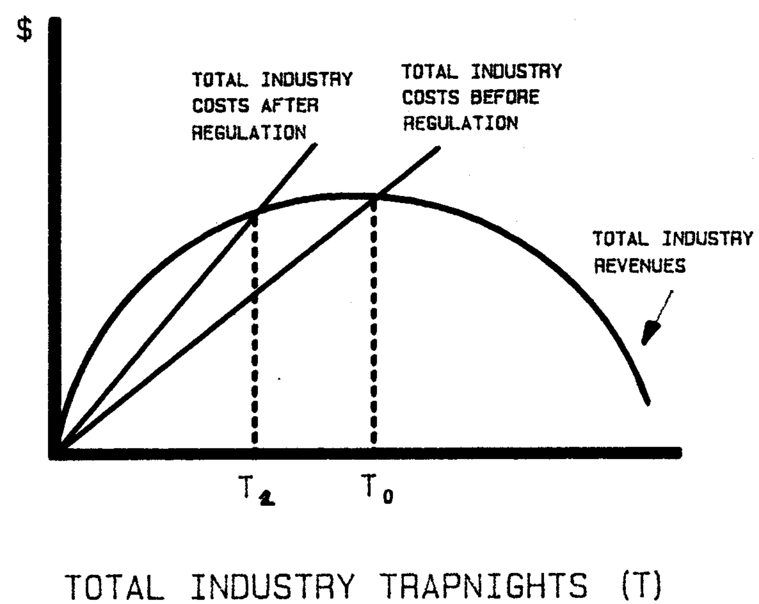

FIGURE 2B.

EFFECTS OF TRAP AND TRIP LIMITS ON THE TYPICAL ENTERPRISE

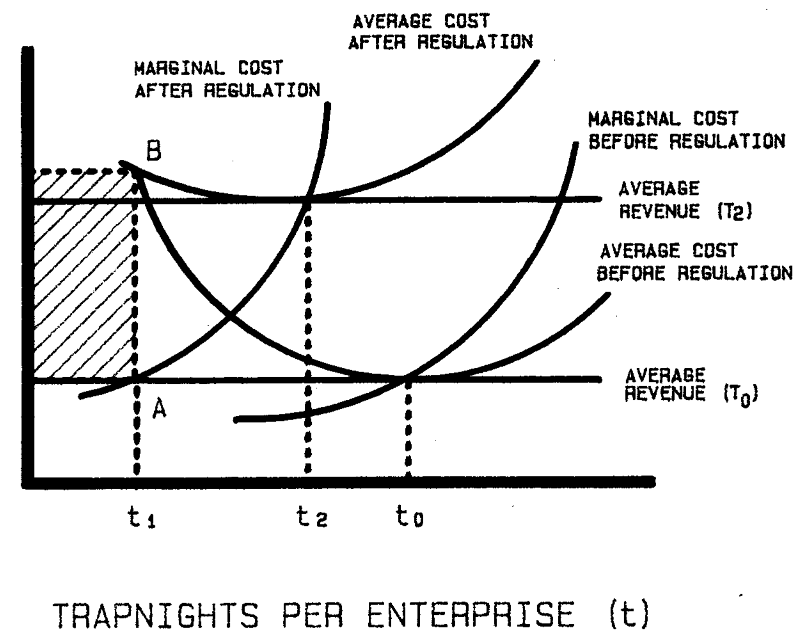

FIGURE 3A.

SENSITIVITY OF VESSEL OPERATING PROFITS TO CHANGES IN TRAPS FISHED PER DAY: BY VESSEL CLASS

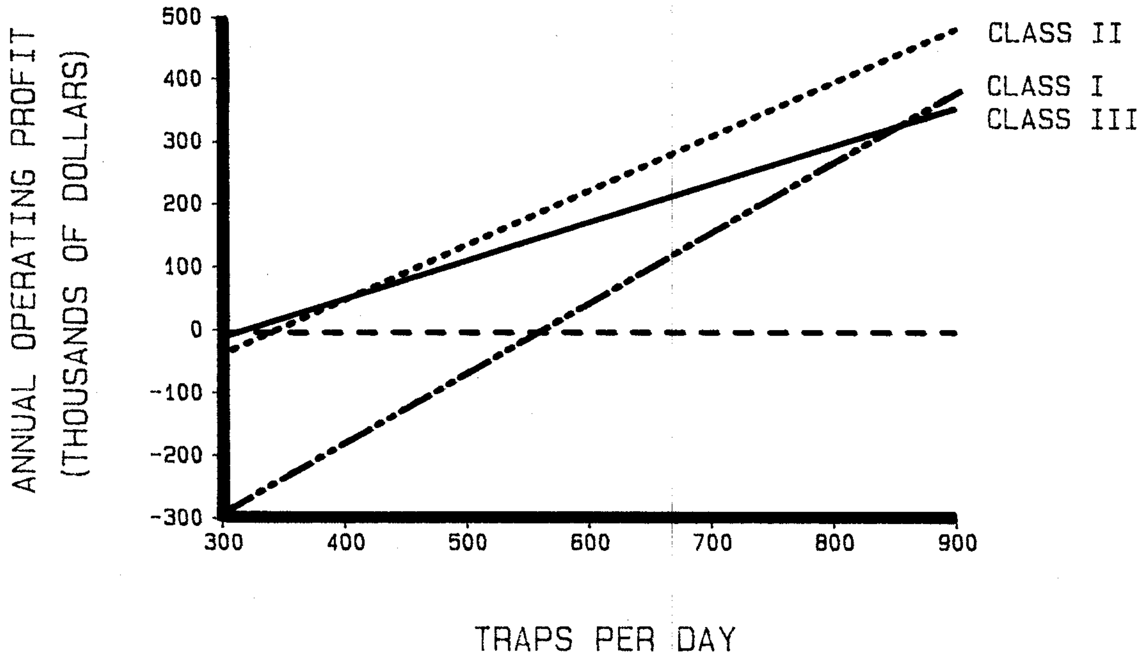

FIGURE 3B.

SENSITIVITY OF VESSEL OPERATING PROFITS TO CHANGES IN TRIPS TAKEN PER YEAR: BY VESSEL CLASS

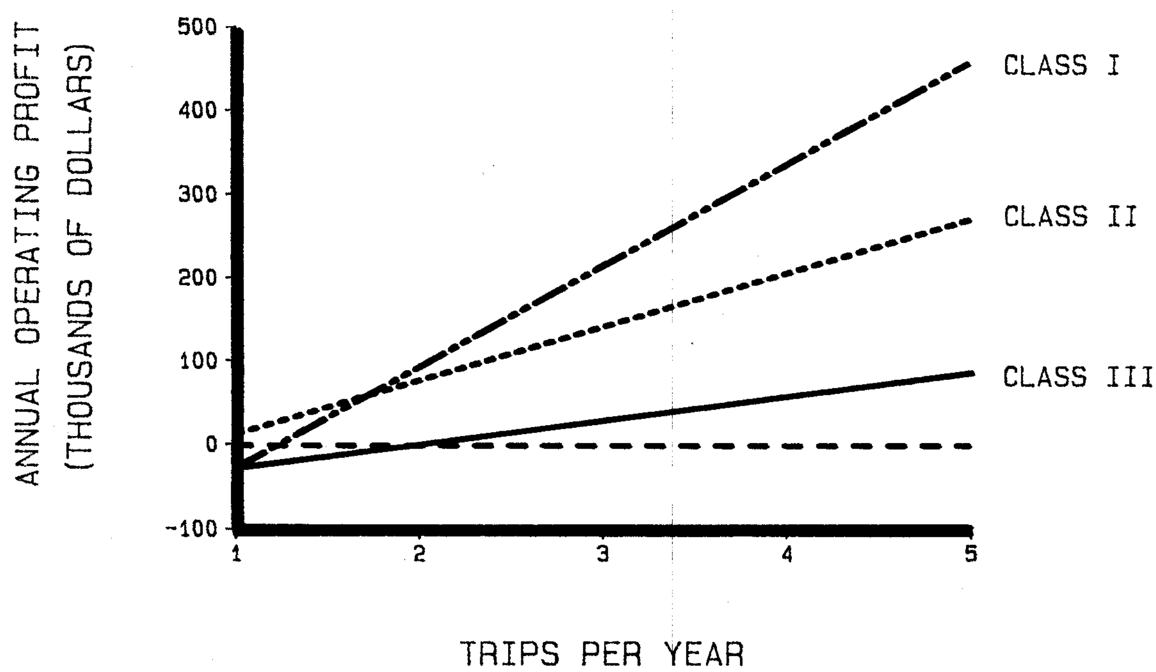

FIGURE 4.

SEASONALITY OF INDUSTRY EFFORT: 1984-86

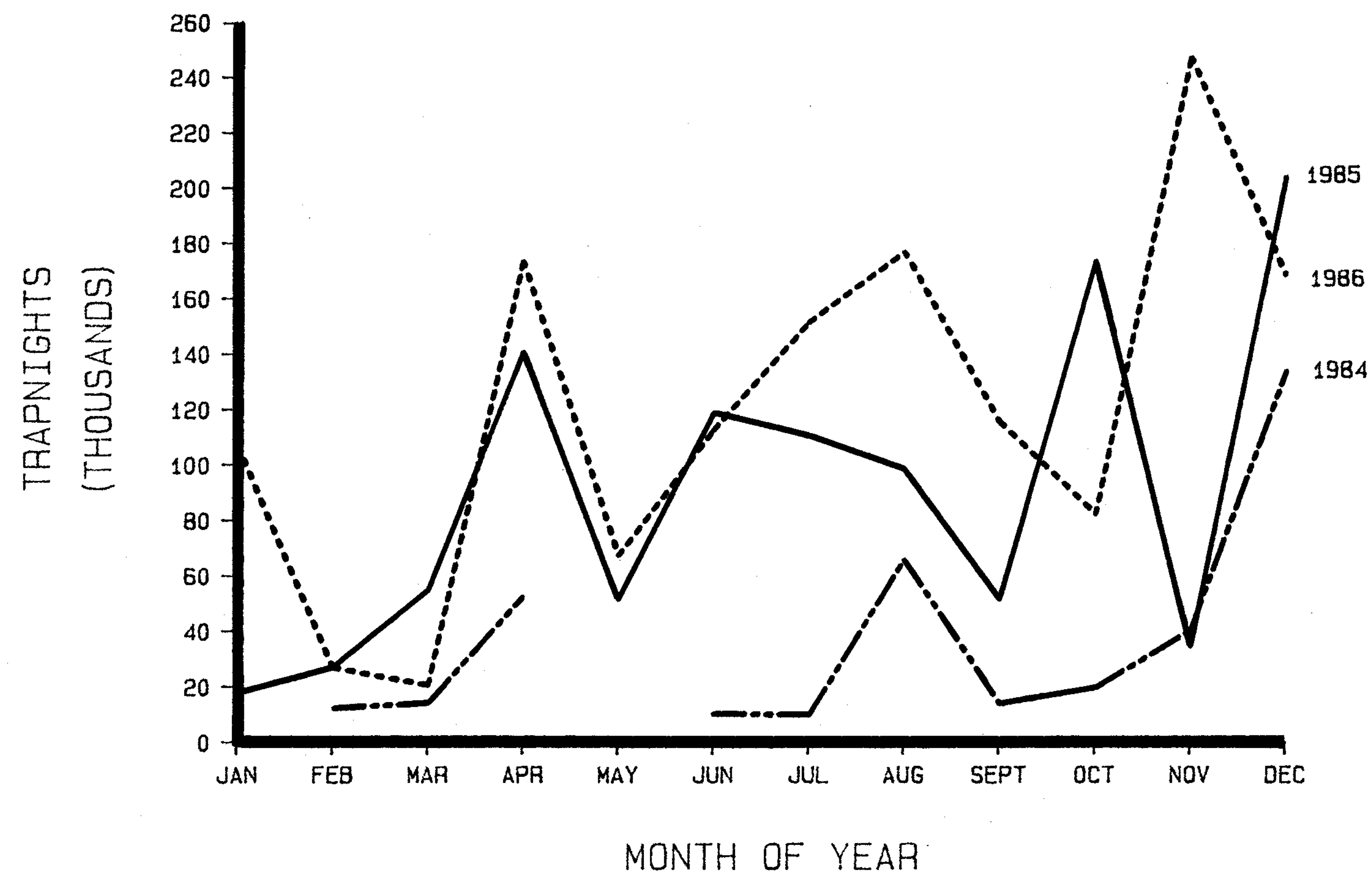

FIGURE 5.

SENSITIVITY OF VESSEL OPERATING PROFITS TO CHANGES IN DAYS FISHED PER YEAR: BY VESSEL CLASS

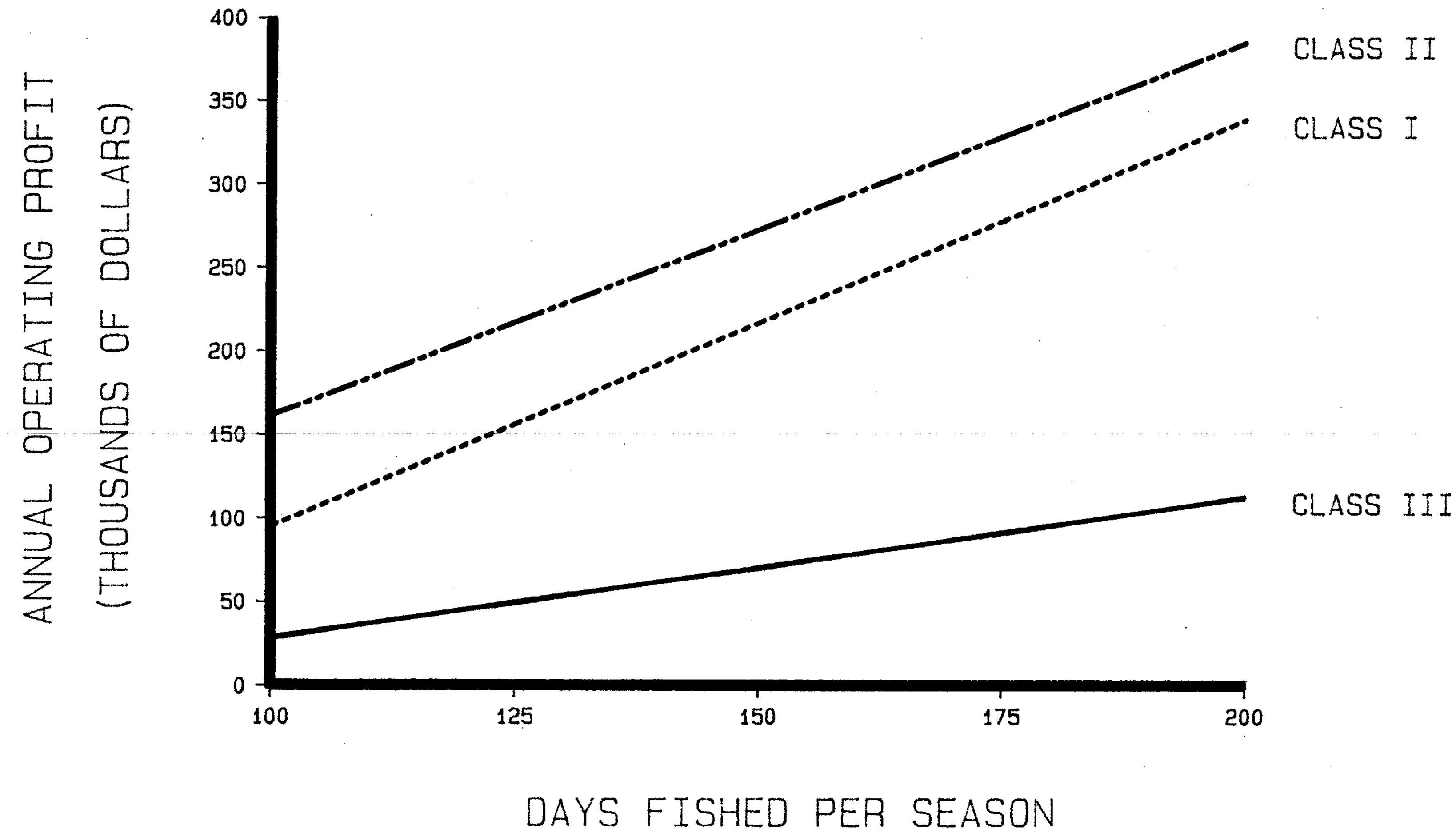

FIGURE 6.

EFFECTS OF AREA CLOSURES ON THE INDUSTRY